KIRCHER

The Relative Efficiency of Land-Surveying Methods

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THE RELATIVE EFFICIENCY OF LAND-SURVEYING METHODS

BY

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THESIS

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This is to certify that the thesis of PAUL KIRCHER entitled THE RELATIVE EFFICIENCY OF LAND-SURVEYING METHODS was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Instructor in Civil Engineering.

Recommendation approved:

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Professor of Civil Engineering.

C O N T E N T S

PREFACE

Work on this thesis was started late in November, 1910, by Mr. Martin F. Connelly and the writer. The cold and muddy winter months caused so much delay that nothing was accomplished until the latter part of the following February, when good weather again made work at a normal speed possible.

The aim throughout has been to make the data as normal as possible. Caution should be observed, however, in the use of the results. The work to be conclusive would need many more repetitions than were possible in the limited time at the writer's disposal. While the results may not be absolutely accurate it is quite apparent that they are enough so as to indicate the most efficient method.

The writer wishes to thank Mr. G. W. Pickels for his kind and helpful suggestions. He also wishes to acknowlege the good suggestions obtained from the thesis by Mr. Connelly, '11, upon this subject.

INTRODUCTION

In the practice of surveying there are many methods that are used without question; not because they have been found by experiment to be the best but simply because of a custom that has grown up. These methods frequently owe their origin to the instruments to which they were first adapted. With the introduction of different and improved types of instruments, they have continued their existence principally because there was no surveyor with sufficient courage to risk his reputation on an unaccepted method.

The method of area surveying is an example of this type of practice. An investigation of text books shows that it is the only method discussed and accepted, and an observation of the common practice brings one to the same conclusion. It is one that is well adapted to the compass, and in all probability owes its origin to that instrument. There are however two other methods of farm surveying that might be used, namely the radiation and intersection methods. But only one of these, the radiation method, will be found upon closer examination to be especially adapted to farm surveying.

The discussion of the various methods will be taken up in three chapters under the following heads: (1) traverse, (2) radiation, (3) intersection. Each method will first be described, after which a discussion of the various steps will be made, and then, in the case of the first two, an example will be given. For reasons that will be given, the third was

not investigated and hence no example can be shown. A comparison of the results and a discussion of the advantages of the various methods will be found in the last chapter entitled "conclusions".

The first field contained approximately 100 acres and was surveyed first by the traverse and then by the radiation method. The time consumed by the instrument work and the chaining was noted along with the regular field data, Since the location of lost or obliterated corners does not affect the subject under discussion the corners of the fields were assumed to be located. To make certain that no special conditions had made the results inaccurate the surveys were repeated. A survey of a field approximately double the size of the first was then made as a check upon the speed and accuracy under changed conditions.

CHAPTER I

THE TRAVERSE METHOD

To survey a field by the traverse method five distinct steps are necessary, viz.:

1. The corners of the field are set.
2. Traverse stations are located near each corner and referred to it. When distance or topography prevents a sight between corners intermediate stations are set.
3. A set-up is made over each corner and the angle between the adjacent corners is measured.
4. The length of each side is measured.
5. The areas are computed.

For reasons given in the introduction the first step will not be discussed.

The best position possible for a traverse station is directly over the corner. Since it is usually impossible to set up over corners of the field, owing to the fences on the boundary lines, the traverse stations must be located either in- or outside of the field. The various ways of locating the traverse stations are shown in Figs. 1, 2, 3, and 4. In Fig. 1 the stations are located at random and are tied in to the original corners by measureing the coordinates. In Fig. 2 the traverse lines are located so as to be

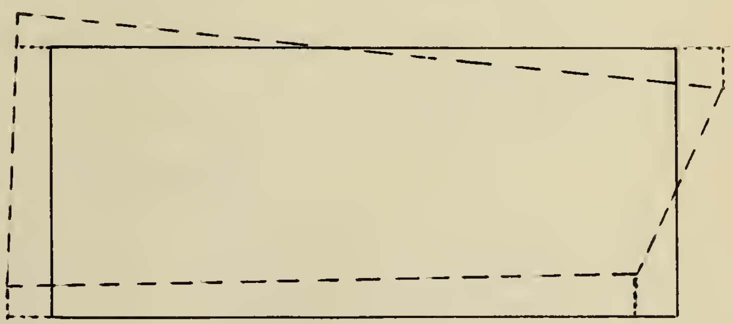

Fig. 1

parallel to the boundary lines. This makes the angles equal to those at the corners of the field and permits direct measurement of the lengths of the

Fig. 2

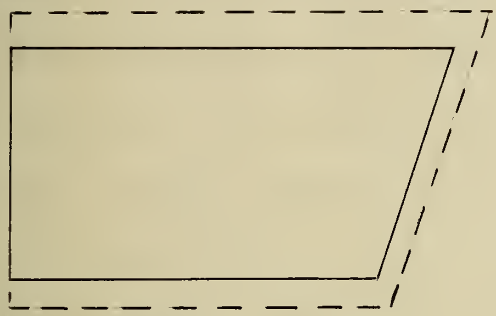

Fig. 3

sides. Should one or more of the boundary lines permit a sight to be taken directly over it, the method shown in Fig. 3 may be used. When distance or topography prevents a sight between corners, as in Fig. 4, an intermediate station may be set arbitrarily. The length and bearing of the

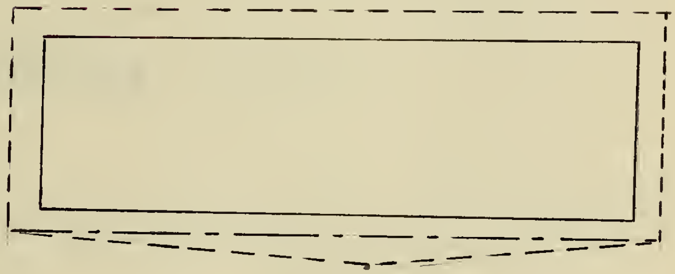

Fig. 4

line that connects the two traverse stations must then be computed, which reduces the problem to one of the three that have just been considered.

The measurement of the angles should always be made by repetition. This prevents all small errors as well as allows a greater precision. In most cases two repetitions will suffice as this gives the necessary check as well as giving results to the half-minute. A final check can be made on the angles of the field by aplying the formula, Σ included angles=2n-4 right angles, where n is the number of sides. This check cannot be made, however until the entire survey is completed.

The fourth step is the one in which the most errors are likely to occur. The measurements should be taken with an ordinary 100 ft. steel

tape. The mistake of dropping one hundred feet is one that is often made. This of course shows up in the computations but the question arises as to in which side the error was made.

The best way to compute the area is by the method of lattitudes and departures. Should the method shown in Fig. 1 be used, corrections equal to the coordinates of the corners of the transit stations must be included. the data were taken using traverse lines parallel to the sides of the field. Below is given a complete set of field notes and the computation of the area of the field. The form of the notes is especially recommended for the reason that the area may be found with but one set of logarithms.

FIELD NOTES AND COMPUTATIONS

Mar. 3, 1911, P. Kircher, Inst., M. F. Connelly, Rod., Temp. 35°, Weatherclear windy, Air, boiling.

Station occupied.	Station sighted.	Triple angle	Angle	Distance feet	Notes
1	n 5				
	2	267°-31'	89°-10'-20"	1603.5	Offset 2ft.
2	1				
	3	362°-58'	90°-46'-00"	2616.9	" 10 "
3	2				
	4	268°-41'	89°-33'-40"	1507.5	" 4 "
4	3				
	5	398°-33'	132°-51'-00"	139.8	" 3 "
5	4				
	1	412°-59'	137°-39'-00"	2524.3	" 1 "
		Check	540°-00'-00"		

Line	1-2	2-3	3-4	4-5	5-1	Error
Bearing	S89-10-20-E	S00-03-40W	N89-30-00W	N42-31-00W	N00-00-00E	
Length	1603.5	2616.9	1507.5	139.8	2524.3	
Log.	3.205069	3.417795	3.178257	2.155507	0.000000	
Log.Cos.	8.159761	0.000000	7.940842	9.868670	0.000000	
Log. Lat.	1.364830	3.417795	1.119099	2.014177	0.000000	
Latitude	23.15	2616.9	13.15	103.3	2524.3	+1.0
Log.Sin.	9.999955	7.027798	9.999983	9.839439	0.000000	
Log.Dep.	3.295928	0.425993	3.199243	1.973446	0.000000	
Departure	1693.33	2.79	1507.36	94.93	0.00	-1.95

Triangle	1	2	3	4	5	6
Log. 0.5	9.698970	9.698970	9.698977	9.698970		
Log.Lat.	1.364830	3.417795	1.119099	2.014177	1.119099	3.417795
Log. Dep.	3.203024	0.445793	3.178340	1.973946	1.973946	3.205024
Log.Area	4.268824	3.562358	3.996309	3.687093	3.093044	6.622819
Area	18570.5	365.0	9915.0	4865.0	1239.0	4195843.0

Total Area = 1+6-2-3-4-5 = 4,194,743 sq.ft. = 96.08 Ac.

CHAPTER II

THE RADIATION METHOD

To survey a field by the radiation method five distinct steps, analogous to those of the traverse method, are necessary, viz.;

1. The corners of the field are set.
2. Radiation points are located about the field where necessary.
3. A set-up is made over each point and the angles of which it is the vertex measured.
4. The lengths of the legs of each angle included in step 3 are measured.
5. The areas are computed.

For the same reason given in Chapter I the first step will not be discussed.

The location of the radiation points is determined by two factors, namely, the size of the field and the accessability of the corners. When a field, such as is shown in Fig. 5 is to be surveyed, the best location for a radiation point is near its center. The area of such a field may be computed when the four angles at the center and the four radial distances are known. Fields up to approximately 169 acres may be surveyed by this method, provided the topography permits. The saving in chaining by this method can be seen from the figure. In addition there is the saving in time due to

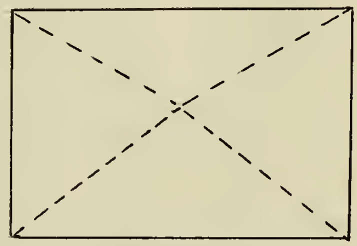

Fig. 5

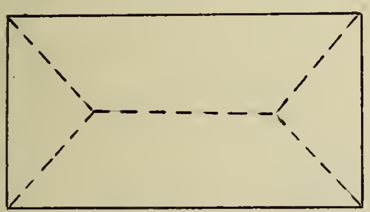

Fig. 6

the fact that only one set-up is needed. When the topography will not permit all the corners to be seen from one point, two or more stations will be required. Where possible these should be located as shown in Fig.6. The most economical location for the point would be at the place at which it makes an angle of 60° with the adjacent corners. This is not usually the most accessable point however and so it may be taken as a general rule that the best location for the point is as near to the side as it can conveniently be placed.

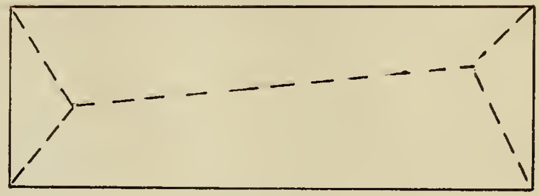

Fig. 7

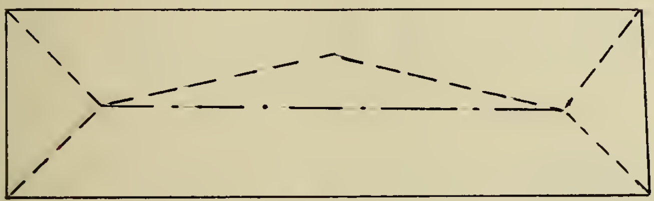

Fig. 8

Should the field be long and under 2000 feet in width, the radiation points may best be located as shown in Fig. 7. If the field is so long that two radiation points within sight of one another then one of the points is established as in the preceeding case. A transit station is next established from it on a line approximately parallel to the boundary line and as far away as the topography will permit. The second radiation point is then placed on the prolongation of this line. Another way would be to run a transit traverse between the two radiation points, which in this case would have to be established previously accord-

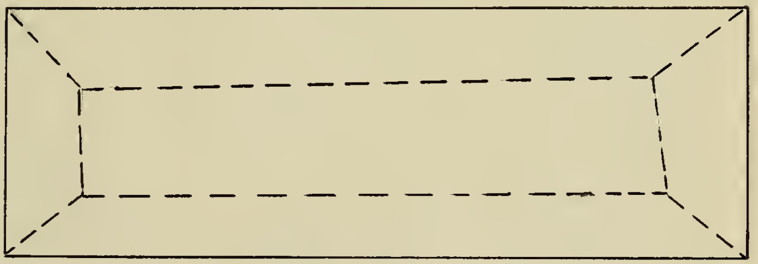

Fig. 9

ing to principles illustrated in Fig. 8. If the field is very large the method shown in Fig. 9 may be used. This virtually amounts to running a transit traverse within the field and tying-in the corners to it. The saving in chaining can also be seen from the figure. There is a reduction in the number of set-ups required when the field is of such a size that in the traverse method two or more set-ups would be necessary for each side. At each radiation point in any one of these methods, the sum of all the angles about it is found and should equal 360°.

For a small field it might be best to read all the angles first and then measure the lengths of the legs of the angles. Usually it is best, however, to take them as the measurement of the angles about each radiation point is completed. The measurement of these radial lines presents really the only valid objection to the radiation method in that it does not give any definite check on the accuracy of the work. If a blunder in measuring is made it will escape detection unless the surveyor is so familiar with the field that he will notice the error when the field is platted. A stadia reading for distance would prevent blunders of this kind and should therefore, always be taken. A flag-pole is quite accurate enough for this purpose. If the top of the pole is graduated in tenths of feet, ten foot errors can be detected. There remains only the danger of taking the wrong reading when the 100-foot end of the tape is used and the reading comes between 45 and 55 feet. Readings around this mark should therefore be taken with great care.

The method used in computing the area consists of dividing the field into a number of triangles and computing the area of each one. The computation shown below is that of the data taken from the same field illust-

rated in the last chapter.

SURVEY OF 80-ACRE FIELD BY RADIATION METHOD

Kircher, Inst., Connelly, Rod., Weather - clear, Temp. - 55°, Air - windy.

STATION OCCUPIED.	STATION SIGHTED.	TRIPLE ANGLE.	ANGLE	DISTANCE feet	NOTES
1	A				
	B	519°-14'-00"	173°-04'-40"	822.1	
1	B				
	2	293°-31'-00"	97°-50'-20"	2032.0	
1	2				
	A	267°-15'-00"	89°-50'-00"	784.4	
2	1				
	C	341°-03'-00"	113°-43'-00"	1149.7	
2	C				
	D	311°-08'-00"	103°43'-00"	744.2	
2	D				
	E	32°-30'-00"	10°-50'-00"	742.6	
			360°-00'-00"		

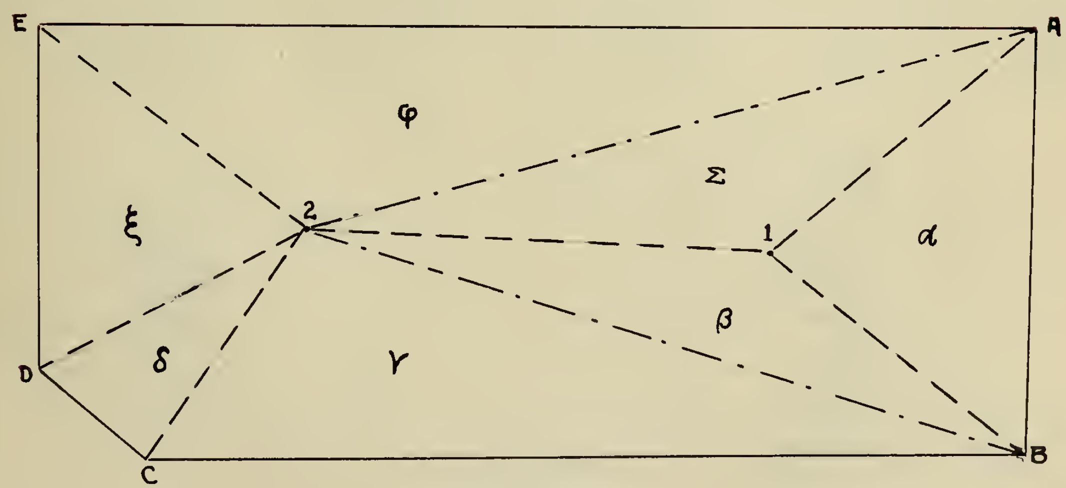

Fig. 10

COMPUTATIONS

$$\overline{A2}^2 = \overline{A1}^2 + \overline{1\text{-}2}^2 - 2\cdot\overline{A1}\cdot\overline{1\text{-}2}\cdot\cos\overline{A12}$$

$$= 734.4^2 + 2032.0^2 + 2\times 734.4\times 0.0160$$

$$A2 = 2179.9$$

$$\overline{B2}^2 = \overline{B1}^2 + \overline{1\text{-}2}^2 - 2\cdot\overline{B1}\cdot\overline{1\text{-}2}\cdot\cos\overline{B12}$$

$$= 822.1^2 + 2032.0^2 + 2\times 822.1\times 2032.0\times 0.13649$$

$$= 2293.5$$

Triangle	α
log. 0.5	= 9.698970
" B1	= 2.914925
" A1	= 2.894538
log sin A1B	= 9.081065
" area	= 4.589498
Area	= 38860.0

Triangle	β
Log. 0.5	= 9.698970
" B1	= 2.914925
" 1-2	= 3.307920
" sin B12	= 9.995922
" area	= 5.917737
Area	= 827,440.0

Triangle	γ
log. 0.5	=9.698970
" B2	=3.360498
" 2C	=3.060586
" sin B2C	=9.998979
" area	=6.119033
Area	= 1,314,320.0

Triangle	δ
log. 0.5	= 9.697970
" 2C	= 3.060586
" 2D	= 2.871690
" sin C2D	= 9.987465
" area	= 5.618711
Area	= 415,634.0

Triangle	ξ
log. 0.5	= 9.698970
" 2D	= 2.871690
" E2	= 2.870755
" sin E2D	= 9.274049
" area	= 4.715464
Area	= 51,946.0

Triangle	φ
log. 0.5	= 9.698970
" E2	= 2.870755
" A2	= 3.337720
" sin E2A	= 9.971123
log.area	= 5.788635
Area	= 756,081.0

Triangle	Σ
log. 0.5	= 9.698970
" A1	= 2.894538
" 12	= 3.307920
" sin A12	= 9.999944
" area	= 5.901372
Area	= 796,842.0

Area of Δ α =	38860
" " Δ β =	827440
" " Δ γ =	1315320
" " Δ δ =	415634
" " Δ ξ =	51936
" " Δ φ =	756081
" " Δ Σ =	796842
Total area =	4205223 sq. ft.
=	96.06acres

CHAPTER III

THE INTERSECTION METHOD

As has been stated the intersection method is not much used. Possibly the clearest way of showing the reasons for this is by explaining the method. The method consists in locating two points in or about the field to be surveyed so that the corners of the field will be visible from each of the points selected. The line connecting these points is called a base line. Its length is first carefully measured and then the angles that the corners of the field form with the ends of the line are measured. From Fig. 11 it can be seen that this divides the field into a series of triangles, two angles and the included side of each being known or so related to the rest of the field that the unknown parts can be calculated. The area of the field can then be found by trigonometry.

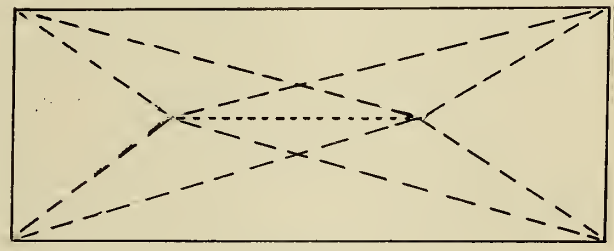

Fig. 11

When carefully done a field can be surveyed with a greater degree of accuracy than with any other method. The work is simple as only two set-ups are needed and the distance to chain is short. There are however several reasons why this method is a difficult one. The first difficulty lies in the fact that the topography is usually such that it is impossible to find points such that all corners of the field are visible from each of them. Since this is an essential feature of the method, the number of fields to which it is applicable is very limited. Another difficulty lies in the fact that an error in the length of the base

line, increases the error in the field proportionately to the ratio of the base line to the sides of the field. A third difficulty is found in measuring the small angles to a sufficient degree of accuracy. The method of repetitions helps considedably and should always be used.

Farm surveys usually present these objectional features. Therefore this method can seldom be used and is not recommended for farm surveys.

TABLE showing the RESULTS of the VARIOUS SURVEYS

FIELD	METHOD USED	DIST. CHAINED feet	DIFF. in CHAINED DIST.—feet	% of TRAVERSE DISTANCE	NO. of SET-UPS	TIME in min. OF				DIFFERENCE IN TIME BETWEEN RADIATION AND TRAVERSE METODS IN		AREA OF FIELD IN	
						PRELIMINARY	INSTRUMENT	CHAINING	TOTAL	min.	%	sq. ft.	ac.
1	T*	8292.0			5	65	125	100	290			4194743	96.08
	R	6275.0	2117.0	25.2	2	75	90	60	225	65	22.4	4193865	96.06
2	T	8391.2			5	60	120	100	280			4193784	96.06
	R	6253.9	2137.3	25.4	2	65	85	70	220	60	21.4	4193764	96.06
3	T	11950.2			5	120	195	150	465			9694270	222.04
	R	8818.3	3131.9	26.2	2	95	155	115	365	100	21.5	9695320	222.06
4	T	11953.0			5	115	185	150	450			9693429	222.02
	R	8800.4	3151.6	26.4	2	90	155	110	355	95	21.1	9694509	222.05

* T- Traverse

R- Radiation

CHAPTER IV

CONCLUSIONS

The results have been summarized in the table on page 15, and they bear out the statement made in the earlier part of this thesis that the radiation method is well adapted to farm surveying for the following reasons:

1. No offsets are required, which decreases the time consumed in setting stakes. In general a saving in time of over 20% can be effected.

2. The number of set-ups that are required is decreased, thereby reducing the time of instrument work.

3. The chaining is greatly decreased. For the fields in question the decrease exceeded 25% of the chaining required by the traverse method.

4. The total time required is considerably less. In the cases investigated the total time saved exceeded 20 % of that consumed in the traverse method.

Usually the areas can be computed faster from data taken by the traverse method, but this increases the time of one man's work rather than that of a party.

The traverse method has the advantage that the error of closure may be computed and is a check on the accuracy of the field work. The errors of surveying usually consist of small errors in observation and blunders. The first of these is negligible. The second may be avoided by a stadia reading for distance so that the error of closure is not a necessary check. The stadia-measurement check may be obtained in either of these methods so that there is no reason why a blunder should remain undiscovered.

From the table it cam be seen that either of these methods are accurate enough for all practical purposes. Hence the radiation method should receive preferrence on account of its speed.